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IS 13368 (1992): Method of test for double inlet centrifugal fans (industrial type) [ETD 5: Electric Fans]

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दोहरे अन्तर्गम वाले अपकेन्द्रीय पंखों (औद्योगिक टाइप) की परीक्षण पद्धति

Indian Standard

METHOD OF TEST FOR DOUBLE INLET CENTRIFUGAL FANS (INDUSTRIAL TYPE)

UDC 621·635 : 620·1

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

November 1992 **Price Group 4**

Electric Fans Sectional Committee, ETD 05

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Electric Fans Sectional Committee had been approved by the Electrotechnical Division Council.

The standard has been formulated with a view to standardize the method of test of double inlet fan to determine the main parameters and technical characteristics.

In reporting the result of a test or analysis, made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

This standard covers the method of test for air delivery for double inlet centrifugal fans.

Indian Standard

METHOD OF TEST FOR DOUBLE INLET CENTRIFUGAL FANS (INDUSTRIAL TYPE)

1 SCOPE

1.1 This standard covers the method of test for air delivery test for double inlet centrifugal fans.

1.2 Double inlet centrifugal fans can be tested at manufacturers works by fitting a test duct at the outlet of the fan. Since it is inconvenient to provide long duct at the outlet for fans having discharge direction other than horizontal, testing method described hereinafter is valid for fans having horizontal discharge. Nevertheless, the method can be successfully applied for other discharge directions if the fan can be rotated for horizontal discharge for testing purpose only.

2 GENERAL CONDITIONS OF TEST

2.1 Test Voltage and Frequency

Unless otherwise specified, the tests shall be carried out at rated voltage and frequency.

2.1.1 When a rated voltage is indicated on the name plate, the tests shall be conducted at the rated voltage. If the fan is specified for two or more distinct rated voltages with three or more supply terminals, the tests shall be carried out at the most unfavourable voltage. In case of doubt, the tests shall be carried out at all voltages.

2.1.2 When a rated voltage range is indicated on the name plate, the test shall be conducted at the mean of the upper and lower limits of the range provided that the upper limit does not exceed the lower limit by more than 10 percent. If the upper limit exceeds this value, the test shall be conducted at the voltage corresponding to either the upper limit or the lower limit whichever is more unfavourable to the particular test.

2.1.3 *Limits of Voltage Variation*

The variation in the test voltage shall not exceed ± 2 percent of the test voltage during air delivery tests. While taking the current and watt readings during these tests, however, the voltage shall be maintained at the test voltage.

2.2 For a fan rated with a range of frequency, the test shall be made at the frequency, which gives the most unfavourable results. Tolerance on frequency shall be ± 1 percent.

2.3 Limits of Error of Electrical Instruments

The ammeters, voltmeters and wattmeters used for type tests shall have a Class index 0·5 or better [*see* IS 1248 (Part 1) : 1963]. For routine and acceptance tests, instruments of Class index 2 may be used.

2.4 Determinations

The number of determinations required to establish the performance of fan over the working range will depend on the shapes of the various characteristics curves. Plans shall be made to vary the opening of the throttling device in such a way that the test points will be well spaced. For smooth characteristics, atleast six determinations shall be made. Additional determinations may be required to define curves which are not smooth. When performance at one point of operation only is required, at least three determinations shall be made to define a short curve which includes that point.

2.5 Equilibrium

Equilibrium conditions shall be established before each determination. To test for equilibrium, trial observations shall be made until steady readings are obtained. Ranges of air delivery over which equilibrium cannot be established shall be recorded.

3 TESTING EQUIPMENT

3.1 Test Duct

A duct may be incorporated in a laboratory set-up to provide a measuring station or to simulate the conditions the fan is expected to encounter in service or both. The dimension '*D*' in the the test set up figure is the inside diameter of a circular cross-section duct or the equivalent diameter of a rectangular cross-section duct with inside transverse dimension '*a*' and '*b*' where $D=\sqrt{4ab/\pi}$. The test duct shall be straight and have uniform circular cross-sections. Also it shall be at least 10 diameters long with the pitot traverse plane located between 8·5 and 8·75 diameters from the upstream end.

Outlet ducts used to provide measuring stations shall be not more than 5% larger or smaller than fan outlet area.

3.1.1 *Transformation Pieces*

Transformation pieces shall be used when a test duct with a measuring station is to be connected to the fan and if it is of a size or shape that differs from the fan connection. Such pieces shall not contain any converging element that makes an angle with the duct axis of greater than 7·5 degrees or a diverging element that makes an angle with the duct axis of greater than 3·5 degrees. The axes of fan and test duct shall coincide (*see* Fig. 2).

3.1.2 *Straighteners*

Straighteners shall be used in all ducts which provide measuring stations. The downstream plane of the straightener shall be located between 5 and 5·25 duct diameters upstream of the plane of the pitot traverse. The form of the straightener shall be as specified in Fig. 3.

3.1.3 *Throttling Devices*

Throttling devices may be used to control the point of operation of the fan. Such devices shall be located at the end of the duct and should be symmetrical about the duct.

3.2 Test Set Up

The set up should be as given in Fig. 1.

This set up may be used for test of fans intended to rated with outlet ducts and with or without inlet ducts.

3.2.1 *Leakage*

The duct and other parts shall be designed to withstand the pressure and other forces to be encountered. All joints between the fan and the measuring station shall be sufficiently tight.

3.3 The symbols and subscripts are given in Annex A.

4 PROCEDURE

4.1 Data to be Recorded

4.1.1 *Test Unit and Set Up*

The description of the test and set up unit shall be recorded. Dimensions should be checked against a drawing and a copy of the drawing attached to the data.

4.1.2 *Instruments*

The instruments and apparatus used in the test shall be listed.

4.1.3 *Test Data*

Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible.

4.1.3.1 *All tests*

For all types of test, three readings of ambient dry-bulb temperature (t_{do}), ambient wet-bulb temperature (t_{wo}), ambient barometric pressure (p_b), fan outlet dry bulb temperature (t_{d2}), fan speed (N) and power input to motor (W) shall be recorded unless the readings are steady in which case only one need be recorded.

4.1.3.2 *Pitot test*

For pitot traverse tests, one reading each of velocity pressure (P_{v3r}) and static pressure (P_{s3r}) shall be recorded for each pitot station. In addition, three readings of traverse-plane dry bulb temperature (t_{d3}) shall be recorded unless the readings are steady in which case only one need be recorded.

4.1.3.3 *Low pressure tests*

For test where P_s is less than 1000 Pa, the temperatures may be considered uniform throughout the test set up and only t_{do} and t_{wo} need be measured.

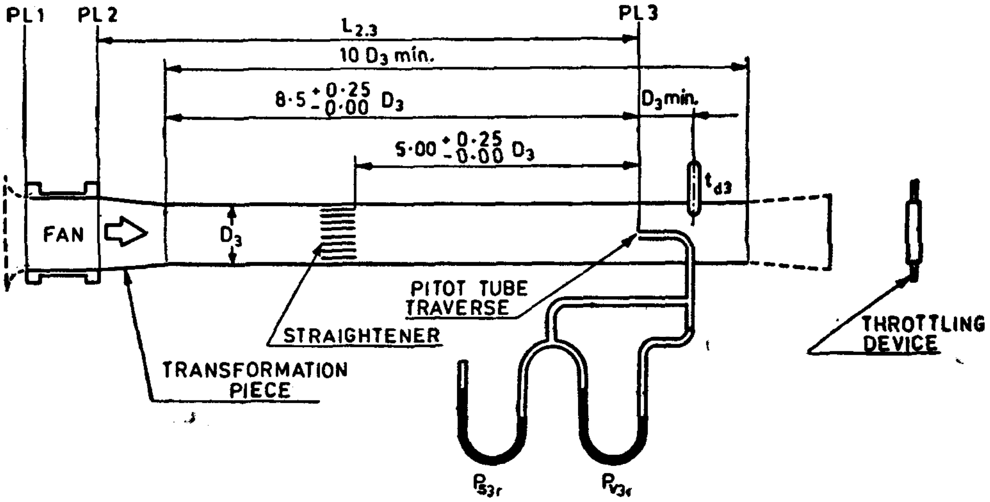
4.1.3.4 *Personnel*

Names of test personnel shall be listed with the data for which they are responsible.

5 CALCULATIONS

5.1 Atmospheric Air Density

The density of atmospheric air (ρ_o) shall be determined from instruments, taken in general test area, of dry-bulb temperature (t_{do}), wet-bulb temperature (t_{wo}) and the barometric pressure (p_b) using either standard charts or by analytical calculation.



All dimensions in millimetres.

FLOW AND PRESSURE FORMULAE

$$P_{v3} = \left(\frac{\Sigma\sqrt{P_{v3r}}}{n}\right)^2$$

$$V_3 = 5.567\,7\sqrt{\frac{P_{v3}}{\rho_3}}$$

$$Q_3 = V_3 A_3$$

$$Q = Q_3\left(\frac{\rho_3}{\rho_x}\right)$$

$$P_{s3} = \frac{\Sigma P_{s3r}}{n}$$

$$P_v = P_{v3}\left(\frac{A_3}{A_2}\right)^2\left(\frac{\rho_3}{\rho_2}\right)$$

$$P_{t1} = 0$$

$$P_{t2} = P_{s3} + P_{v3} + f\left(\frac{L_{e\cdot3}}{D_{h3}} + \frac{L_e}{D_{h3}}\right)P_{v3}$$

$$P_t = P_{t2} - P_{t1}$$

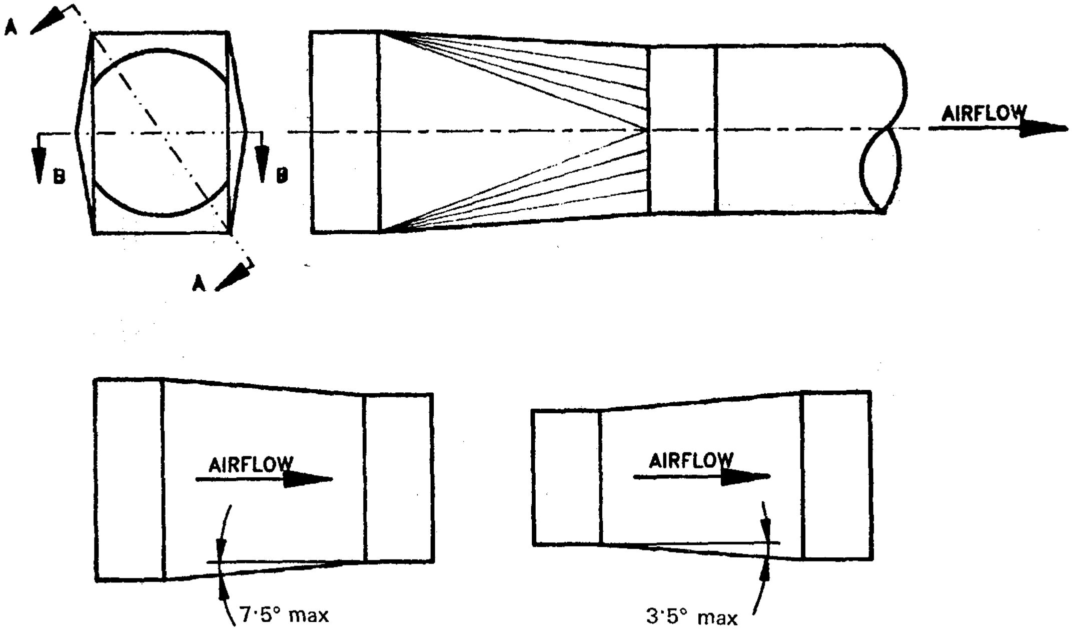
$$P_s = P_t - P_v$$

NOTES

1 Dotted lines on fan inlet indicate an inlet bell which may be used to simulate an inlet duct. The inlet bell friction loss shall not be considered.

2 Dotted lines on the outlet indicate a diffuser cone which may be used to approach more nearly free delivery.

FIG. 1 OUTLET DUCT SET UP — PITOT TRAVERSE IN OUTLET DUCT



SECTION AA
(CONVERGING SECTION)

SECTION BB
(DIVERGING SECTION)

FIG. 2 TRANSFORMATION PIECE

5.1.1 *Duct Air Density*

The density of air in a duct at plane '*X*' ρ_x may be calculated by correcting the density of atmospheric air (ρ_o) for the pressure (p_{sx}) and temperature (t_{dx}) at plane 'X' using the following relationship:

$$\rho_x = \rho_o \left(\frac{t_{do}+273}{t_{dx}+273} \right) \left(\frac{P_{sx}+p_b}{p_b} \right)$$

If P_{sx} is numerically less than 1 000 P_a ρ_x may be considered equal to ρ_o.

5.2 Fan Flow Rate At Test Conditions

5.2.1 *Pitot Traverse*

The fan flow rate may be calculated from velocity pressure measurements (P_{v3r}) taken by Pitot traverse.

5.2.1.1 *Velocity pressure*

The velocity pressure (P_{v3}) corresponding to the average velocity shall be obtained by taking square roots of the individual measurements (P_{v3r}), summing the roots, dividing the sum by the number of measurements (n), and squaring the quotient as indicated by

$$P_{v3} = \left(\frac{\Sigma \sqrt{P_{v3}r}}{n} \right)^2$$

5.2.1.2 *Velocity*

The average velocity (V_3) shall be obtained from the density at the plane of traverse (ρ_3) and the corresponding velocity pressure (P_{v3}) using

$$V_3 = 5{\cdot}567\,7\sqrt{P_{v3}\,/\,\rho_3}$$

5.2.1.3 *Flow rate*

The flow rate (Q_3) at the pitot traverse plane shall be obtained from the velocity (V_3) and the area (A_3) using

$$Q_3 = V_3 \,.\, A_3 \,.$$

5.2.1.4 *Fan flow rate*

The fan flow rate at test conditions (Q) shall be obtained from the equation of continuity.

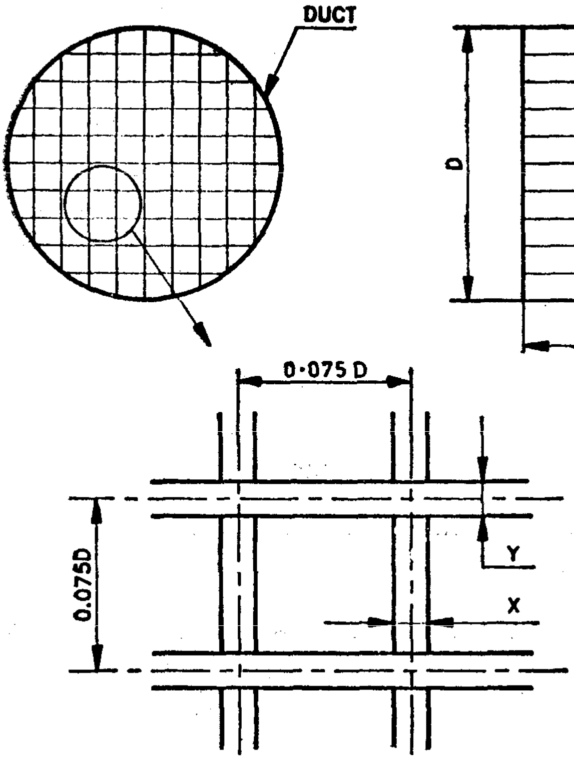
$$Q = \frac{Q_3\,\rho_3}{\rho_x}$$

5.3 Fan Velocity Pressure at Test Conditions

5.3.1 *Pitot Traverse*

When pitot traverse measurements are made, the fan velocity pressure (P_v) shall be determined from the velocity pressure (P_{v3}) using

$$P_v = P_{v3} \left(\frac{\rho_3}{\rho_2} \right) \left(\frac{A_3}{A_2} \right)^2$$



NOTE — All dimensions shall be within 0·005 D except '*Y*' which shall not exceed 0·005 D.

EQUIVALENT LENGTHS OF STRAIGHTENERS

$\frac{y}{D}$	$\frac{L_e}{D}$
0	15·0
0·001	15·8
0·002	16·6
0·003	17·5
0·004	18·4
0·005	19·4

FIG. 3 FLOW STRAIGHTENER

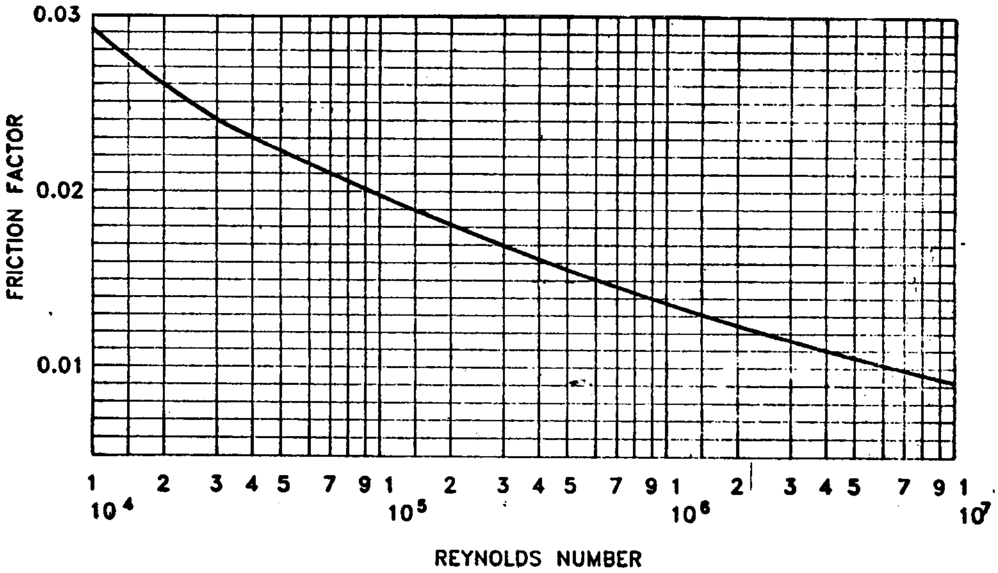


FIG. 4 FRICTION FACTORS FOR DUCTS

Whenever P_{s3} and P_{s2} differ by less than 1 000 Pa, ρ_3 may be considered as ρ_2.

5.4 Fan Total Pressure at Test Conditions

The fan total pressure shall be calculated from measurements of pressures in ducts corrected for pressure losses in measuring ducts which occur between the fan and the measuring stations.

5.4.1 *Pitot Traverse*

When a pitot traverse is used for pressure measurement, the average velocity pressure (P_{v3}) shall be as determined in **5.2.1.1**, the average velocity (V_3) as in **5.2.1.2** and the average static pressure (P_{s3}) shall be calculated from

$$P_{s3} = \frac{\Sigma P_{s3r}}{n}$$

5.4.2 *Pressure Losses — Pitot Outlet Duct*

When the fan discharges into the duct with a pitot traverse, P_{t2} shall be considered equal to the sum of the average static pressure (P_{s3}) and the average velocity pressure (P_{v3}) corrected for the friction due to both the equivalent length of the straightener (L_e) and the length of duct ($L_{2,3}$) between the fan and the measuring station, so that

$$P_{t2}=P_{s3}+P_{v3+f}\left(\frac{L_{2,3}}{D_{h3}}+\frac{L_e}{D_{h3}}\right)P_{v3}$$

where D_h is the Hydraulic diameter for the duct and '*f*' is the coefficient of friction.

The hydraulic diameter for round ducts is actual diameter (D). The hydraulic diameter for rectangular ducts shall be calculated from the inside traverse dimensions 'a' and 'b' using

$$D_h = 2ab / (a+b)$$

The coefficient of friction (f) shall be determined from :

$$f = 0{\cdot}14/R_e^{0.17}$$

where R_e = Reynolds Number.

$$= \frac{D_h V \rho}{\mu}$$

Where μ is the absolute viscosity of air under test condition, $\mu=(11+0{\cdot}018\ t_d)\times 1{\cdot}488\times 10^{-6}$.

The value of μ is $1{\cdot}8\times 10^{-5}$ P_{as} for temperatures ranging between 4°C and 38°C.

5.5 Fan Static Pressure at Test Conditions

The fan static pressure (P_s) shall be calculated from

$$P_s = P_t - P_v .$$

5.6 Fan Power Input at Test Conditions

The power input to the motor can be checked from power meter. If a calibrated electric motor is used to measure input, the fan power input (H) may be calculated from the power input to the motor (W) and the motor efficiency (η) using

$$H = W\eta$$

5.7 Fan Efficiency

5.7.1 *Fan Power Output*

The fan power output (H_0) would be proportional to the product of fan flow rate (Q) and the fan total pressure (P_t) if air were incompressible. Since air is compressible, thermodynamic effects influence output and a compressibility coefficient (k_p) must be applied making output proportional to $Q \cdot P_t \cdot k_p$.

$$H_0 = Q \cdot P_t \cdot k_p$$

Standard chart for k_p is available.

If the fan total pressure is less than 3 000 Pa, the value of k_p will usually be greater than 0·99 in which case the value of the k_p may be taken as unity.

5.7.2 *Fan Total Efficiency*

The fan total efficiency (η_t) is the ratio of fan power output to fan power input or

$$\eta_t = \frac{Q \cdot P_t k_p}{H}$$

6 REPORT AND RESULTS OF TEST

6.1 Report

The report of a fan test shall include object, results, test data, and descriptions of the test fan including appurtenances, test set up and test instruments.

6.2 Performance Curves

The results of a fan test shall be presented as performance curves. Curves shall be drawn with fan flow rate as abscissa. Fan pressure and fan power input shall be plotted as ordinates.

Fan total pressure, fan static pressure or both may be drawn depending upon requirement. Curves with fan total efficiency as ordinates may be drawn. Barometric pressure shall be tested when fan pressures exceed 2 500 Pa.

6.2.1 *Test Points*

The results for each determination shall be shown on the performance curve as a series of circled points, one for each variable plotted as ordinate.

6.2.2 *Discontinuities*

When discontinuities exist they shall be identified with a broken line. If equilibrium cannot be established for any determination, the curves joining the points for that determination with adjacent points shall be drawn as broken lines.

7 TOLERANCES ON RATINGS

The observed results expressed as percentage of the ratings assigned by the manufacturer shall be within the following limits:

Characteristic	*Tolerence* Percent
Volume flow	– 5
Static or total efficiency expressed as a percentage	– 5
Total power input	+10
Speed	±10

Where a tolerance in one direction is emitted there is no restriction on the value in that direction.

ANNEX A

(*Clause* 3.3)

SYMBOLS AND SUBSCRIPTS

Symbol	Description	Unit
D	Diameter and equivalent diameter	m
D_h	Hydraulic diameter	m
f	Coefficient of friction	Dimensionless.
H	Fan power input	W
L_e	Equivalent length of straightener	m
P_s	Fan static pressure	Pa
P_{sx}	Static pressure at plan x	Pa
P_t	Fan total pressure	Pa
P_b	Corrected barometer pressure	Pa
Q	Fan flow rate	r/s
t_d	Dry bulb temperature	°C
t_w	Wet bulb temperature	°C
V	Velocity	m/s
ρ	Fan air density	kg/m^3
A	Area of cross section	m^2

Subscript	Description
1	Plane 1 (fan inlet)
2	Plane 2 (fan outlet)
3	Plane 3 (Pitot traverse station)

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